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A Report On
Calculating Volumetric
Storage Capacities
May 22, 1994



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Calculating Reservoir Volumes

A Three Method Comparison

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Flood Control District of Maricopa County

May 22, 1994

I. Purpose

This report was written at the request of the Hydrology Division to address the capability of the procedure used by the GIS Division for calculating reservoir volumes. To illustrate the effectiveness of our preferred procedure, a comparison of two other viable methods will be presented. We will also show that the ARC/INFO™ TIN has the same window of error as the preferred industry standard, SiteWorks™.

The first method to be examined is SiteWorks™, Intergraph's MicroStation™ automated drafting software, designed to accommodate sophisticated terrain modeling applications. The second method to be discussed in the comparison analysis is the Conic Method for determining Reservoir Volumes. The final method in the analysis is the Triangulated Irregular Network (TIN) module of ARC/INFO™. TIN is a generic tool used for analyzing and modeling surface information.

This report will demonstrate that the ARC/INFO™ TIN module and SiteWorks™ are viable and interchangeable methods for determining the volumetric capacity of reservoirs. It will also show that the Conic Method is inappropriate for this application.

II. Automated Drafting Software

The first method to be discussed is SiteWorks™, a software package capable of calculating the volumetric storage capacity of a dam. Terrain model point and line data in ASCII files can be directly imported into SiteWorks™. Mass points (random spot elevations) and breaklines (a connected series of two or more datapoints) are created from the ASCII data. The data is then fed into an efficient algorithm that connects the input data into a series of triangles of approximately equal size; i.e. a TIN. The TIN or combination of point and triangle data, comprise the surface area otherwise known as the digital terrain model (DTM). A DTM is a structured datafile used specifically for the digital modeling of surface terrain. The accuracy of the data generated is dependant upon the quality and density of the original source DTM.

III. The Conic Method for Determining Reservoir Volumes

The second method to be discussed in our comparison analysis is the Conic Method for determining Reservoir Volumes. This method assumes that the volume is zero at the lowest elevation given, even if the surface area is greater than zero at that point. Given the elevation, E_1 , the volume of water contained can be computed by making several calculations. We let h denote the vertical distance between elevations $E_2 - E_1$, our

surface base areas A_1 and A_2 . The final step in determining the volume is to add the area A_1 and A_2 to the square root of the product of the areas and multiply by the vertical distance $h/3$ (Figure 1).

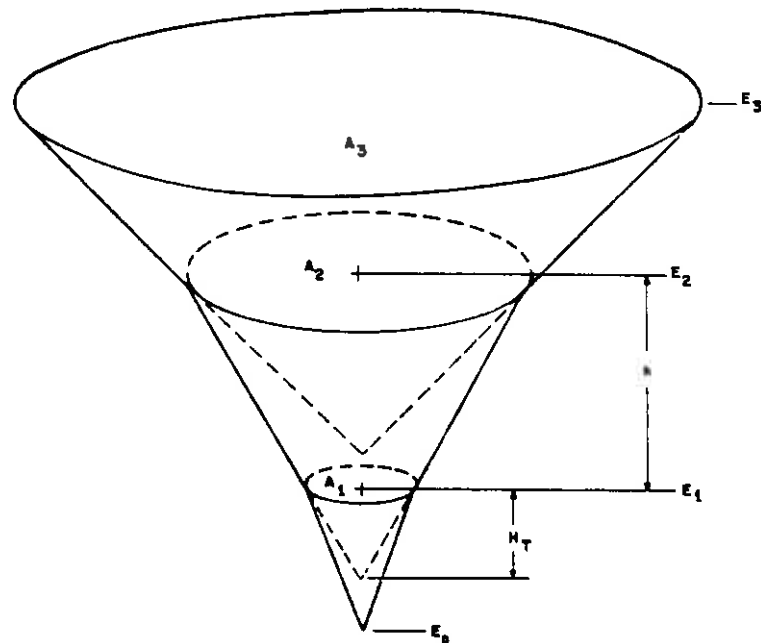


Figure 1 (HEC-1 Flood Hydrograph Package Users Manual)

The hand calculations of the Conic Method are within $\pm .10\%$ of the automated method of SiteWorks™. However, it should be mentioned that no natural feature is a true conic. The Conic Method is best suited for calculations in which the volume shape is conic. Furthermore, the Conic Method for calculating reservoir volumes is not expected or considered to be as accurate as the numerical methods of analysis.

IV. ARC/INFO™ Triangulated Irregular Network

The third method utilizes TIN, a module of ARC/INFO™. TIN is a generic surface

moduling tool. Volumetric storage capacities for dams are easily derived using TIN. The TIN data structure utilizes two basic elements: points (x, y, z) and a series of edges joining these points to form triangles. Using the TIN module, the surface can be represented by converting the line and polygon vertices into a series of x, y, z coordinates (triangular facets.) Given a base elevation and the x, y, z coordinates of all of the triangular facets, the entire volume above the base elevation can be computed (Figure 2).

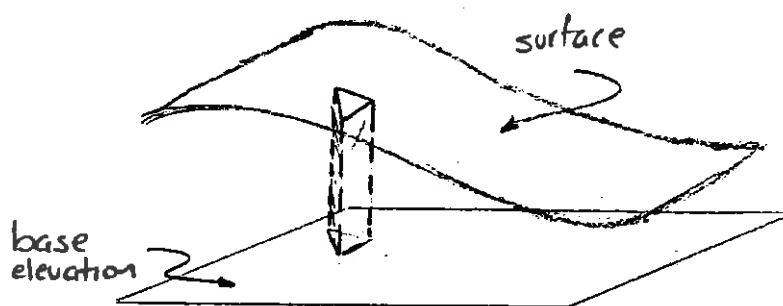


Figure 2

However, since we are interested in the storage capacities for a dam, we must invert the surface model by multiplying the surface by "-1" (Figure 3 & 4). Water storage capacities calculated by TIN are $\pm 0.01\%$ of the SiteWorks™ method. The accuracy of the data generated is dependant upon the quality and density of the original source DTM.

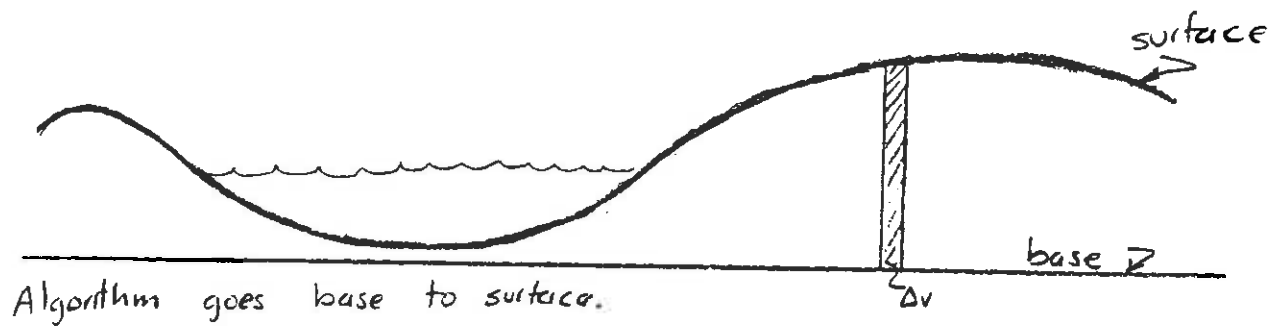


Figure 3

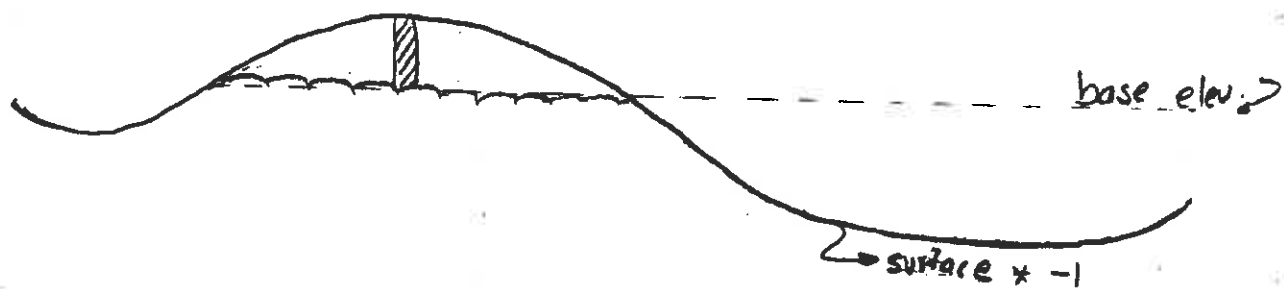


Figure 4

V. Findings

As per contractor requirement, all data received by the Hydrology Division is in ARC/INFO™ format. The Geographic Information Systems (GIS) section at the Flood Control District of Maricopa County has GIS trained experts along with hardware to easily and accurately accommodate the frequent conversions required by the Hydrology Division. ARC/INFO™ TIN results are within $\pm .01\%$ of the Siteworks™ method and can be considered interchangeable methods for calculating volumetric capacity of reservoirs (Figure 5).

Sunset Dam

Elevation	TIN	Area Sq. Ft.	Conic Method	% of Error	Siteworks	% of Error
	Volume Cu. Ft.		Volume Cu. Ft.	TIN & Conic	Volume Cu. Ft.	TIN & Siteworks
2,122.00	1,012,684.00	207,098.40	1,097,572.10	8.30%	1,014,309.00	0.10%
2,123.00	1,233,867.00	230,761.20	1,250,862.86	1.30%	1,233,878.40	0.00%
2,124.00	1,474,401.00	250,543.80	1,493,832.50	1.30%	1,474,426.80	0.00%
2,125.00	1,738,371.00	274,826.20	1,756,936.27	1.06%	1,738,419.30	0.00%
2,126.00	2,023,811.00	296,084.10	2,041,054.26	0.80%	2,023,887.60	0.00%
2,127.00	2,330,726.00	315,500.00	2,344,347.26	0.58%	2,330,823.60	0.00%
2,128.00	2,654,628.00	332,119.10	2,669,672.81	0.50%	2,654,650.80	0.00%
2,129.00	2,998,991.00	352,725.30	3,012,328.07	0.40%	2,998,638.90	-0.01%
2,130.00	3,361,496.00	369,969.70	3,373,749.98	0.30%	3,360,036.60	-0.40%

Figure 5

VI. Conclusions

This report was written to address the issue of performing volumetric calculations in-house. The report compares three methods to illustrate that the ARC/INFO™ TIN and Siteworks™ are viable and accurate methods for calculating volumetric reservoir capacities. The results of all three methods are dependant upon the accuracy, quality and density of the original source DTM. Both ARC/INFO™ TIN and Siteworks™ yield practically identical results within the same window of error. The Conic Method, however, proved to be more suited towards applications involving (literally) conic shaped volumes. Since the Flood Control District of Maricopa County utilizes ARC/INFO™ TIN which has an established link to the database, along with experienced technicians trained in ARC/INFO™ TIN, and all hardware requirements for the software, ARC/INFO™ TIN is the cost effective choice for volumetric calculations.